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Smuts of Jowar (*Sorghum*) in the Bombay Presidency

BY

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PREFACE.

THE study of smuts of Jowar (*Sorghum*) is of no small importance as the following paper will show. The present paper embodies the results of observations and experiments made by the writer during the last five years. It does not claim to be an exhaustive study but mainly notes the kinds of smuts attacking the crop, the damage they do, some facts in their life-histories, and the means of checking them so far known. The study is being continued. It is hoped to carry out similar work on other important smuts on Bajari (*Pennisetum typhoideum*), Rala (*Setaria italica*), and Nachani (*Eleusine coracana*).

The writer spent two months in the Mycological Laboratory, Research Institute, Pusa, while working up the paper. While he was there, considerable help and advice was rendered to him by Dr. E. J. Butler, Imperial Mycologist, Pusa. The literature and specimens in his laboratory were freely consulted and the illustrations were also prepared there. For all this he is greatly indebted to him. His acknowledgments are also due to the Superintendents of the College Farm, Poona, the Ganeshkhind Botanical Gardens, Kirkee, and the Dharwar Farm, for having kindly undertaken for him the field experiments.

G. S. KULKARNI.

AGRICULTURAL COLLEGE,
Poona, 17th March, 1917.

Smuts of Jowar (*Sorghum*) in the Bombay Presidency.

[*Received for publication on 30th July, 1917.*]

The word Jowar as used in the Bombay Presidency indicates all the cultivated varieties of *Andropogon Sorghum* Brot. In India the crop occupies a third place among the cultivated crops, in acreage, covering an area of twenty-one million acres[1], while in the Bombay Presidency it ranks first, occupying more than eight million[2] acres. This area represents about one-sixth of the total cropped area of the Presidency and is more than one-third of the total area devoted to food grain crops. It is thus an important field crop in every part of the Presidency except in the Konkan, where, owing to excessive rainfall, it gives place to rice, and consequently occupies a small area, and in the Panch Mahals where maize (*Zea Mays*) is the staple. The reason why this crop is largely grown is because of its two-fold use as food and fodder. Its grain forms the chief article of diet of a large section of the population and its stems form first class fodder which is the main stay of the cattle. Any diseases affecting such an important and widely grown crop are, therefore, well worth studying.

The number of fungus diseases affecting this crop is large, but by far the most important of them from the economic point of view are those that cause the well-known smut disease. This disease has been long known to the cultivators under various names as *Kani* or *Kajali* in Marathi, *Kadige* in Kanarese, *Angario* in Gujarati, and *Kani* in Sindhi. It is also known in all other parts of India, especially in Madras, the Central Provinces, and Burma where it is very common, and throughout the world wherever varieties of *Andropogon Sorghum* are grown. Thus it is reported to occur on Durra or Kafir corn in Africa, Sorghum or Broom corn in Southern Europe and America, Guinea corn in the West Indies, and Sorghum or Amber cane in Australia. Investigators in these countries have discovered and described six or seven kinds of smuts on this crop. So far as India is concerned, however, only three of these smuts have previously been identified[3], though, as will be seen

[1] *Statistical Abstract relating to British India from 1904-05 to 1913-14*, page 132.
[2] *Season and Crop Report of the Bombay Presidency* for the year 1915-1916, statement III.
[3] Sydow, H. V. P. and Butler, E. J. "Fungi Indiæ Orientalis" I. *Ann. Mycol.*, IV, 1906, pp. 425 and 427.

below, a fourth has now to be added. In Madras Barber[1] has published an account of the three commoner forms. But they have not received a thorough study either in their scientific aspects or in relation to practical agricultural applications.

There are four distinct smuts that occur on Jowar in this area ;—

1. *Grain Smut.* Here the normal grains in the head are transformed into enlarged, elongated, conical bodies protected for some time by a greyish membrane which on rupture exposes a dusty mass of black spores.

2. *Loose Smut.* This differs from the above in that the affected body has a fragile membrane which ruptures even before the head comes out. On exposure the head presents a dark sooty appearance.

3. *Long Smut.* Here the affected individual grains are much more elongated than either of the above two, up to as much as 1½ inches in length.

4. *Whole-head Smut.* Here instead of individual grains being involved, the whole of the head, including the rachis, is converted into a fibrous spore mass.

Distribution.

Every district, in which Jowar is cultivated, suffers more or less severely from the disease. The virulence and distribution seem to depend upon (1) the character of the seed sown, (2) the locality and (3) the variety of the crop. Of these the first is the most important.

(1) *Character of the seed.* This expression is used to denote freedom or otherwise from contamination of seed with spores previous to sowing. It has been found that smut can be increased by mixing the spores with seeds before sowing. In the experiments conducted on the College Farm and the Ganeshkhind Botanical Gardens at Poona, it was observed that in the plots whose seed was dusted with spores smut was found in from 20 to 60 per cent. of the plants as compared with 6 to 8 per cent. in those plots where ordinary bazaar seed was used. It was also seen that in a few cases where the cultivators took care to select their seed only from disease-free fields, they got crops nearly free from smut. But in the majority of cases such care is not taken and the result is that smut is extremely common in all fields.

(2) *Locality.* In general, localities with high rainfall have more smut than those with low rainfall. Thus in the western parts of the Poona, Satara, Belgaum and Dharwar districts, which receive more

[1] Barber, C. A. "Diseases of *Andropogon Sorghum* in the Madras Presidency." *Bull. Dept. of Land Records and Agriculture, Madras*, II, No. 49, 1904, p. 275.

rain owing to their nearness to the Western Ghats, smut is found more abundantly than in the eastern parts of the same districts. Rao Saheb Malharrao Kulkarni, Divisional Inspector of Agriculture, Southern Division, who has done and is doing much work in the campaign of smut prevention, says in his report : "From personal observations of the disease in various parts of the Division, I think smut is more prevalent in parts where the rainfall is more severe. I also find that Kharif *jowar*[1] is more liable to smut than Rabi *jowar*[2], which also leads me to conclude that the greater rainfall in the Kharif season, than in the Rabi, is the cause of more disease in the former season."

In the Rabi tract smut is found to a small extent in the Gadag, Ron, and Navalgund Talukas of the Dharwar District, but is fairly common in the Bijapur, Ahmednagar, and Broach districts, while in the Sholapur District it developes into epidemics of varying severity in some place or other every year.

(3) *Variety of Crop.* It has been found that smut as a rule is more prevalent in the Kharif varieties than in the Rabi.

The Grain Smut is the commonest form found throughout the Presidency on both Kharif and Rabi crops. The Loose Smut is mainly found in the Sholapur District on the Rabi varieties of *Maldandi* and *Dagadi* though occasionally scattered in other parts. The Long Smut is almost confined to Sind but occurs sparingly in the Kathiawar States too. The Whole-head Smut is found sporadically everywhere.

Damage.

To arrive at an exact estimation of the loss caused by these smuts is rather difficult owing to fluctuation in the virulence and frequency of attack. In some years the damage done is considerable, while in others it is much less. There may be considerable variation in the amount of damage in the different fields of the same locality. Thus the attack may vary from 2 to 3 per cent. in places where it is mild to 40 to 50 per cent. in places where it is severe. Enquiries addressed to the members of the district staff of the Bombay Agricultural Department show that in the Broach District the damage varies from 10 to 20 per cent., in Surat from 4 to 10 per cent., in Khandesh from 3 to 7 per cent., in Dharwar from 5 to 15 per cent., and in Belgaum from 3 to 15 per cent. From the experiments made on the Dharwar and Gadag Farms,[3] the loss has been estimated from 20 to 30 per cent. of the yield

[1] The monsoon crop, sown in June-July and harvested in October-November.
[2] The winter crop, sown in September-October and harvested in February-March.
[3] *Annual Report on the experimental work of the Dharwar Agricultural Station* for the year 1910-11, p. 48, Department of Agriculture, Bombay.

per acre. On the Surat Farm where experiments have been conducted since the beginning of the Farm to demonstrate the loss caused by the smut in crops grown from untreated bazaar seed it averages up to 15 per cent. From the estimates made by the writer in the districts in a large number of fields by counting the affected heads in small areas the loss has been found to vary from 6 to 40 per cent. These figures show that the loss caused by the smuts is very great indeed.

Economic Importance.

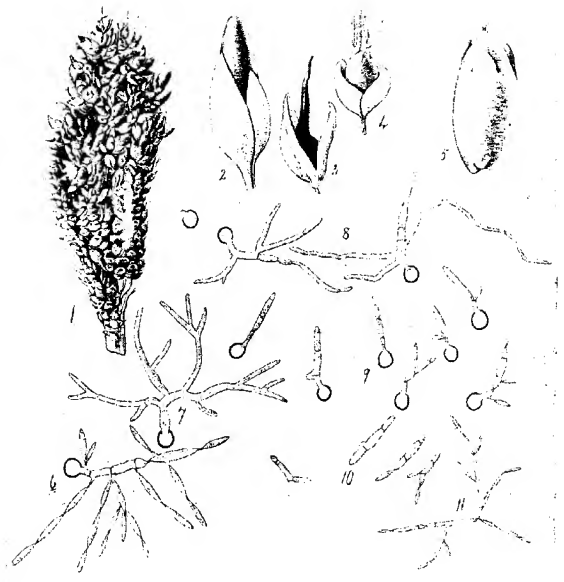
The total acreage of the crop in the Presidency including Sind is 8,102,146 acres[1]. Even taking 10 per cent. as the average loss the total money value of the loss amounts to Rs. 2,02,55,365 (£1,350,357). By far the greater part of this damage is due to the Grain Smut. The Loose Smut and Long Smut occur only in comparatively restricted areas, and, though they cause heavy losses in the localities in which they occur, they are comparatively insignificant when the whole of the Bombay Presidency is considered. The damage from the Whole-head Smut which occurs sporadically everywhere is very little.

Effect of attack on the host.

As a rule it is not possible to detect the presence of the fungus attack in a plant until the appearance of the inflorescence. Till then the infected plant looks exactly like the healthy one in point of vigour and size. In the case of Whole-head Smut, however, the affected plant sometimes can be recognized a little before the smut mass becomes obvious. At flowering time the healthy plant shows a distinct swelling at the top due to the enclosed inflorescence, especially in those varieties which produce big ears, while in the affected plants the swelling is less marked and by a little observation such plants can be easily detected. Mr. P. C. Patil, Acting Deputy Director of Agriculture, Northern Division, informs me that he has seen cultivators' children who could pick out the affected plants before smut comes out and who eat the immature smut sori, which taste quite sweet. Potter[2] also alludes to the edibility of the smut sorus of Sorghum when young. In the case of the Loose Smut again the affected plants occasionally show definite characters by which they may be distinguished before the heads come out. The smut-affected plants, as compared with the normal ones, are rather stunted and their stalks thinner, and in some cases

[1] *Season and Crop Report of the Bombay Presidency* 1915-16, statement III.
[2] Potter A. A. *Phytopathology*, II, 1912, p. 98.

PLATE I



Grain Smut of Jowar (*Sphacelotheca Sorghi*): *1*, smutted ear, × ½; *2*, a sorus magnified; *3*, columella left after the spores have fallen; *4*, sorus not involving stamens; *5*, sorus with stamens involved; *6*, spore germinating with promycelium and sporidia, × 450; *7*, spore germinating with branched germ-tube, × 450; *8*, promycelium with hyphæ in place of sporidia, × 450; *9*, promycelia, some constricted at first septum preparatory to being cast off, × 450; *10*, cast promycelia, × 450; *11*, promycelium with budding chains of sporidia, × 450.

PLATE II

Loose Smut of Jowar (*Sphacelotheca cruenta*): *1*, smutted ear, × ½; *2*, sorus involving stamens magnified; *3*, columella left after the spores have fallen; *4*, spores and their germination, × 460.

there is a tendency to tiller freely, and the affected heads begin to come out long before those of healthy plants (in one experiment as long as two months before the normal ones). There is no such difference observed in the other two smuts.

When the smut masses appear, it is found that the character of each kind of smut differs considerably from those of the others, so that distinction between them without microscopic examination is quite easy. In order to understand the changes in the inflorescence it is necessary in the first place to have a clear idea of the normal inflorescence. The *jowar* inflorescence is composed of paniculate racemes of heteromorphous spikelets so arranged on a central axis as to form a compact or loose head. The ultimate divisions end in branchlets which bear spikelets of which the lower one is sessile and hermaphrodite and the upper two (sometimes only one) are pedicelled and neuter, occasionally male. In the sessile spikelet there are four glumes, of which the fourth is bifid containing an awn in the middle. Within these there are two lodicules, three stamens with capillary filaments and versatile anthers, and in the centre an ovary crowned by two feathery stigmas. The pedicelled spikelets are usually as long as but narrower than the sessile ones. There are also four glumes, though sometimes only the outer two are present.

The diseased ear as a whole does not generally differ from the normal in size and shape and the central axis and its branches are quite free from the attack in the Grain (Plate I) and Long (Plate III, fig. 2) Smuts. In the Loose Smut (Plate II), however, it occasionally assumes a less compact form as compared with the healthy one, and frequently pustules are found on the axis and its branches.

When the main head is attacked, the heads arising laterally in the leaf axils and also the tillers growing from the base of the plant are invariably attacked. Occasionally the main head escapes and only the lateral heads show the disease. This is more common in the case of the Loose Smut. The new shoots springing from the affected plant after it is cut also show the disease.

In the Long Smut only a few sessile spikelets in the head are affected, the pedicelled ones usually escaping. In the Grain Smut both the sessile and pedicelled ones are involved; occasionally some of the latter are free, but the number of diseased spikelets in the heads varies very much. In some only a few are diseased, while in others more than half of them are involved. But in the majority of cases all of them are diseased. In the Loose Smut all the spikelets, both the sessile and pedicelled, are affected, though rarely some escape. Sometimes in this smut peculiar outgrowths (proliferations) of the inflorescence are

observed. The growth may start from the centre of the affected spikelet or as a branch at the base of the main inflorescence. In the former case the growth takes the form of a complete plant formed of a tiny stalk with leaves, nodes, and a rudimentary inflorescence which is also smutted. In the latter case the outer glumes of the spikelet is enlarged into a flag leaf containing in miniature an entire sound inflorescence.

Coming to the glumes, it is seen that their colour is unchanged in the Long and Grain Smuts though sometimes in the latter it is changed to purple. This purple colour, when present, is so very marked that the affected heads can be easily distinguished even in their early stage. In the Loose Smut the colour is changed to a deep green or to a dark purple.

With regard to the size of the glumes they remain unaltered in the Grain and Long Smuts. But in the Loose Smut they undergo a considerable amount of modification. They are usually enlarged, elongated, nearly glabrous, and the nerves on them are very prominent. In size they are from 10 to 20 mm. in length and 5 to 8 mm. in breadth as compared with the 5 to 7 mm. length and 4 to 6 mm. breadth of the normal glumes. The maximum length observed in the first glume was 35 mm. and breadth 10 mm. The awn of the fourth glume in all cases is either suppressed, or, when present, is usually shortened. The lodicules are either unaltered or suppressed.

The pistils and stamens are usually infected before they are very much differentiated in the flower. If the attack is very early, they are not distinguishable as separate organs but form by fusion one solid conical body. In a good many cases, however, the conical body can be seen to be formed out of three stamens and a pistil by the presence of three small points around the central one at the tip, the middle one indicating the pistil, and the three surrounding the stamens. Occasionally the pistil and the filaments are blended together, the anthers remaining quite free. At times the stamens are completely free, the pistil alone being involved. This mode of attack when only the pistil is involved, seems to be rather constant in the Grain Smut in certain Rabi varieties, and the escape or otherwise of the stamens appears to determine the form of the affected body. When the stamens are included in the attack a conical body is formed, when they escape an oblong body with a blunt tip with the stamens surrounding it is the result. In the Loose Smut it is often found that the fusion of stamens and pistils is not quite complete. Each stamen has its own infected body which joins at the base the central main one.

The stigmas usually escape infection and they can be seen in the ripened body at its tip in all the smuts. Eventually they dry up and vanish.

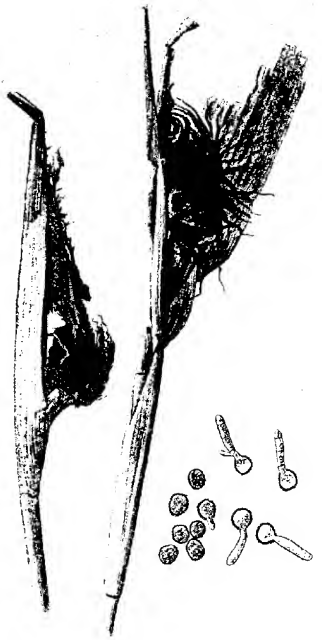


Fig. 1. Whole-head Smut of Jowar (*Sorosporium Reilianum*) smutted ears, × ⅓ spores and their germination, × 300.

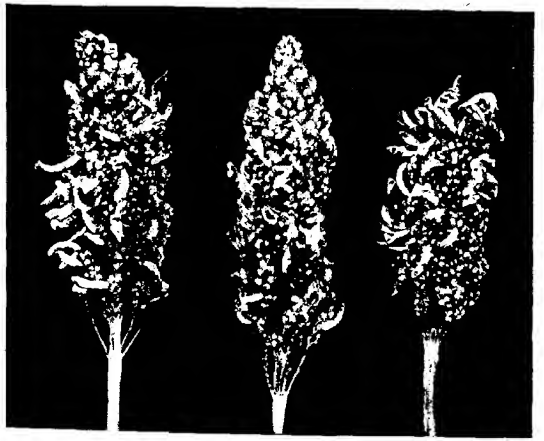


Fig. 2. Long Smut of Jowar (*Tolyposporium filiferum*).

In the early stage the affected body is covered by the glumes and therefore is not visible. It comes out as it grows and on maturity is distinctly seen. It shows great variations with regard to size and shape in the different smuts. In the Grain Smut it is generally, compared with the normal seed, an elongated, sometimes slightly bent when long, thickened, club-shaped body, tapering to a point at the free end. Sometimes it assumes an oblong shape with a blunt end. As already mentioned this is due to the escape of stamens. In the Long Smut it is cylindrical in shape, usually curved, and abruptly coming to a point at the free end. It is from 3 to 12 mm. in length and 2 to 4 mm. in breadth in the Grain Smut; from 3 to 18 mm. in length and 2 to 4 mm. in breadth in the Loose Smut; and in the Long Smut from 6 to 25 mm. in length and from 4 to 6 mm. in breadth.

In the case of the Whole-head Smut (Plate III, fig. 1) the changes produced are quite different from those above described for the other kinds. The whole of the inflorescence, including the rachis, is converted into a fibrous spore mass protected by a whitish membrane which is very transient. In the beginning the sorus is enclosed by the leaf-sheath through which it comes out, either partially or completely exposing a dark spore mass and the ray-like remains of the fibro-vascular threads of the host tissue. Sometimes the affected plants produce a smut-free inflorescence which however is sterile. In such cases the glumes of the spikelets are elongated and decolorized, and hence the head as a whole looks pale and the sorus appears either just below the head itself or lower down on the main stem. Frequently pustules are found on the leaves surrounding the sorus.

The membrane of the sorus in all cases is whitish in colour. In the Grain Smut it is of two sorts. In one case it has a brownish tinge in the early stage, which on maturity turns to dull grey; while in the other it is shining grey and on maturity turns to pale grey. In the Long Smut it is shining greyish-white. In the Whole-head Smut it is bright porcelain-white when fresh and turns to dull white on drying.

On ripening the membrane usually ruptures and exposes the spores. In the Grain Smut this process is very variable. In some cases the membrane gets broken just after maturity, and in some it remains intact for a time. In others again it is so very tough that it never ruptures unless it sustains some mechanical injury. In the Long Smut it opens, after maturity, usually at the tip, occasionally by cracks in the middle. In the Loose and the Whole-head Smuts it is very transient and ruptures even before the head emerges from the sheath.

Soon after the rupture of the membrane the spores are exposed and scattered by the wind. Afterwards there remains in the sorus nothing

but a slender hard mass of host tissue known as the columella, which differs according to the kind of smut. In the Grain Smut it forms a stiff, slender, rather straight column, narrowing somewhat irregularly from the base towards the apex, and terminating before reaching the end of the sorus. In the Loose Smut it differs from the above in being longer and curved. In the Long Smut it consists of a bundle of 8 to 10, sometimes more, dark brown filaments, usually joined at the base. In the Whole-head Smut it is composed of innumerable solid filaments inextricably tangled into a net-work.

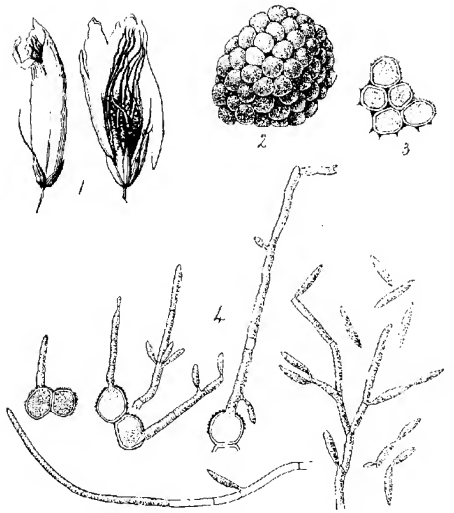
Spores.

In the Grain Smut the spores are powdery and appear dark brown in mass. Singly they are brown, smooth-walled, and 4 to 6μ in diameter. In the Loose Smut they appear quite black in mass, while individually they are dark brown, with minutely pitted walls, very variable in size, usually from 4 to 8μ. In the Long Smut they are granular in mass, being formed in dark coloured balls consisting of numerous spores firmly held together. Singly they are brown in colour, of irregular shape, mostly globular or oblong, thick walled, tubercled, and from 8 to 14μ in size. The spores in the centre of the spore-ball are paler brown than those at the surface and do not clearly show the tubercles on their walls. In the Whole-head Smut they are deep brown in colour, globular or somewhat angular, minutely tubercled, and from 8 to 16μ in size. Sterile cells of subspherical shape, often in groups, are sometime seen scattered in the spore mass.

Germination.

The spores of Grain and Loose Smuts germinate very easily in water. They begin to sprout within 6 hours of sowing and at 12 hours germination is very vigorous. At first a small, hyaline, straight or often bent tube (rarely two) appears, which gradually lengthens and forms what is known as the promycelium. From 2 to 4 transverse septa are soon formed, dividing it into 3 to 5 segments. In the early stages the septa are not clearly seen owing to the granular appearance of the protoplasm, but they are easily made out when stained with cotton blue. The so-called buckle or knee joints are very common. They are formed by a branch growing out from the end of one of the segments, near the septum, and then curving round to effect a communication with the next segment. A knob-like joint is thus formed, and the promycelium is usually bent at

PLATE IV



Long Smut of Jowar (*Tolyposporium filiferum* : *1*, ruptured sori; *2*, a spore ball; *3*, part of same in section, × 450; *4*, germination, × 150.

such joints. Sporidial formation is scarce. When formed the sporidia appear at the tip of the promycelium or laterally at the septa, either just above or below them. They are spindle-shaped and are borne directly on an elongated slender sterigma which soon breaks, so that the sporidia are mostly found free from the main body. They do not seem to bud off secondary sporidia to any great extent. More usually, instead of sporidia, long slender hyphæ, which are frequently of considerable length, grow either from the apex of the promycelium or from the knee-joints or segments. Sometimes the promycelium is not distinct but a branching germ-tube arises in its place. Occasionally the promycelium is cast off wholly from the spore. The mode of germination in the Grain Smut and the Loose Smut is identical except that the promycelium in the Loose Smut is slightly thicker. In nutrient solutions (dung solution or tomato broth) the germination is more vigorous; stouter and thicker promycelia are formed and the sporidia develop very abundantly. The latter are bigger than those in water culture and bud very freely. The formation of knee-joints and of branching germ-tubes or the production of hyphæ instead of sporidia on the promycelium, are less often observed.

The spores of the Long Smut germinate in water, dung solution, tomato broth, or glucose peptone culture solution[1]. But Busse succeeded in germinating them only in the last solution. Germination was observed after 24 hours, a good many spores of each cluster sprouting as a rule. The promycelium is generally 3-celled, longer than either of the above two smuts, and bears sporidia at the tip and laterally from near the septa, often in clusters. These either produce secondary sporidia by budding or grow into long germ-tubes. The promycelium is sometimes much branched, or often instead of a true promycelium the spore germinates by a hypha, the protoplasm of which collects in the upper growing part while the lower becomes empty and cut off by successively formed septa.

The spores of the Whole-head Smut are difficult to germinate. Attempts to germinate them in water or nutrient solutions were not successful. They were tried in different seasons and at various times of the year. The variations of temperature such as 16°, 20°, 30° and 40°C. did not have any effect, although Potter in America has succeeded in getting some germination at 30°C. It is known that freezing sometimes promotes the germination of spores, and, in order to test this, some

[1] This solution is composed of—

Water	400 c.c.
Glucose	8 per cent.
Peptone	1·5 per cent.
Magnesium sulphate	0·1 per cent.

and a trace of sodium phosphate.

were kept in a closed dry test tube in ice for 24 hours. This seemed to have some effect on them as a scanty germination was then obtained on sowing in water.[1] A short, thick promycelium, thicker than those of the three previous smuts, is formed, having 2 to 3 septa. No further progress was seen except a few sporidia which were borne terminally or laterally. Repeated trials did not show any further growth.

Infection.

According to previous workers (*e.g.* Brefeld[2], Clinton[3] and Potter[4]), infection in the Grain and Loose Smuts takes place at the seedling stage through the seed-borne spores. Our out-door experiments both in the field and in pots prove the same thing.

Pot experiments, 1912. Plants were raised in wooden tubs in each of which 13 seeds were put. Before sowing the seed was mixed with spores and was divided into two parts; one part was sown untreated and the other was dipped in 2 per cent. copper sulphate solution for 10 minutes.

Serial No. of pot	No. of seed mixed with spores	Plants grown	Plants smutted
1	13 seeds were dusted with the spores of Loose Smut	13	13
2	13 seeds mixed with Loose Smut spores but treated with 2 per cent. $CuSO_4$ for 10 minutes	13	nil
3	13 seeds mixed with the spores of Grain Smut	13	11
4	Ditto Ditto . .	13	9
5	13 seeds with Grain Smut spores but treated with 2 per cent. $CuSO_4$ for 10 minutes	13	nil

Field experiments, 1914. These were carried out at two places, on the College Farm and the Ganeshkhind Botanical Gardens, in small plots of half a *guntha*[5] in area. All the four smuts were tried. The

[1] The room temperature of the laboratory was 30°C.
[2] Brefeld. "Untersuchungen," XV, 1912, p. 31.
[3] Clinton G. P. "Broom corn smut," *Illinois Agri. Exp. Sta. Bull.* 47, 1897, p. 394.
[4] Potter, A. A. *Phytopathology*, V, 1915, p. 151.
[5] A *guntha* is equal to $\frac{1}{40}$th of an acre.

same process of mixing the spores and then treating half of it with $CuSO_4$ was followed

Serial No. of plot	Treatment	Percentage of attack	Kind of Smut
1	Seed mixed with spores before sowing	20 per cent. in the College Farm and 17 per cent. in Ganeshkhind Botanical Gardens	Grain Smut
2	Seed mixed with spores and then treated with 2 per cent. $CuSO_4$ for 10 minutes	Nil in both the places	
3	Seed mixed with spores before sowing	60 per cent. in the College Farm, 40 per cent. in Ganeshkhind Botanical Gardens	Loose Smut
4	The same seed treated with 2 per cent. $CuSO_4$ for 10 minutes	Nil in both the places	
5	Seed mixed with spores	Ditto . .	Long Smut
6	The same seed treated with 2 per cent. $CuSO_4$ for 10 minutes	Ditto . .	
7	The seed mixed with spores	Ditto . .	Whole-head Smut
8	The same seed treated with 2 per cent. $CuSO_4$ for 10 minutes	Ditto . .	

These experiments show that infection occurs with seed-borne spores in the case of *Grain* and *Loose* Smuts and not in *Long* and *Whole-head* Smuts, and that in the first two copper sulphate seed treatment is effective in checking the disease.

Soil infection in the Grain and Loose Smuts does not seem to take place. It has been found that though spores of both retain their vitality for at least 2 years if kept dry (in certain cases they are said to have been germinated even after $6\frac{1}{2}$ years), still under the ordinary alternating wet and dry conditions of the soil they do not seem to survive more than a few months. They probably germinate on the first fall of rain and perish when drought sets in unless they encounter the host plant. On the Dharwar Farm artificial infection of the soil of two plots, each

of 2 *gunthas* in area, with the spores of the Grain Smut, two months before sowing, did not produce infection in a single plant. Nor did infection occur in the case of pot experiments conducted in Poona. The spores of both the Grain and Loose Smuts were used and they were mixed in the soil 3 months previous to sowing. In these experiments seed before sowing was treated with 2 per cent. copper sulphate solution.

With regard to the Whole-head Smut, however, soil infection seems to be the chief mode of attack. This has been practically established by Potter[1] in America and our observations here also confirm it. Seed treatment does not check it; furthermore the spores germinate irregularly (unlike the Grain and Loose Smuts), many failing to sprout when sown in water, so that they could remain in the soil through several wet and dry periods without losing their vitality and thus infect the seedlings when the next crop is sown. But the number that germinates each time appears to be very small as is evident from the way the disease appears in a few plants scattered through the fields.

In the Long Smut, infection from spores adhering to the grain coats and sown with the seed does not seem to take place as we have already seen, and experience from Sind, where this smut occurs regularly, has shown that seed treatment is not effective in checking the disease. Its further life-history is not known. Whether infection is through the flower or through the spores in the soil from the previous crop is still to be worked out.

No further work was done with regard to the Long and Whole-head Smuts. The work described below refers only to the Grain and Loose Smuts.

Infection appears to take place only when the germ tube of the spore or the sporidium comes in contact with the young cells of the shoot. Entry is effected by the hyphæ growing through the epidermal cells of the primary shoot below the soil level, and the susceptibility is limited to the period of about 2 to 6 days between the moment of germination and the emergence of the first green leaf from its colourless sheath. This period varies somewhat according to temperature and moisture.

In a germinating *jowar* seed we find two members, one the descending axis which comes out first and forms the primary root, the other the ascending axis which forms the shoot. Soon after germination, growth at the base of the bud increases, and consequently a short internode is formed, connecting the seed at one end and the plumulary bud at the other. This internode is known as the mesocotyl, and the sheath enclosing the stem bud is known as the coleoptile. The latter

[1] Potter, A. A. "Head Smut of *Sorghum* and Maize." *Journal, Agri. Res.*, II, 1914, p. 367.

1, infection hyphæ of *Sphacelotheca Sorghi* entering through epidermal cells; 2, hyphæ of same in ground tissue after infection; 3, hyphæ of same in bundle parenchyma; 4, diagramatic sketch of longitudinal section of growing point of *jowar* seedling, showing the position of hyphæ which are mostly in the ground tissue

is soon pierced by the growing leaves of the stem bud, after which the growth of the mesocotyl ceases.

Temperature. At low temperatures *jowar* will germinate very slowly. Its rate of germination increases as the temperature rises and is at its optimum at 36° to 40°C. Thus at 16°C. it takes from 4 to 6 days for the first leaf to appear. At 20° to 23°C. it requires 3 to 4 days; at 30°C. 2 to 3 days and at 37°C. 1½ to 2 days. The spores of both the smuts germinate quite easily at moderate temperatures. The optimum temperature is 20° to 23°C., below or above which the rate of germination falls. At 16°C. about 70 per cent. of the spores of both Grain and Loose Smuts germinate, at 20° to 23°C, about 90 per cent., at 30°C. about 60 per cent., and at 37°C. only 1 to 2 per cent. If the temperature of germination be compared for the spores and the *jowar* seeds, it is found that infection is most likely to succeed at moderate temperatures, say, between 16°C. and 30°C., at which the spores germinate very freely, while the growth of the *jowar* seedling is retarded so that the susceptible stage is prolonged. The temperature, therefore, seems to be the chief controlling factor in the distribution of these smuts. We have already seen Kharif varieties are more susceptible to smut than the Rabi and even in the Kharif the tracts having higher rainfall have more smut than those having less rainfall. As we pass eastwards away from the Western Ghats the rainfall decreases while the temperature gradually rises. The Kharif *jowar* is sown in June-July, when the weather is usually cold and wet and the average temperature is between 21°C. and 27°C., which, as we have already seen, is most favourable for the spores to germinate, while *jowar* germinates rather slowly and consequently the susceptible stage is lengthened and infection is more certain. In the case of Rabi *jowar*, which is usually sown in September-October, the weather is dry and warm and naturally the temperature is higher than in June-July and therefore more favourable for the rapid growth of the *jowar* seedling whose susceptible stage is passed over soon. This is the probable explanation why smut is worse in the Kharif than in the Rabi crop[1].

Moisture. Successful infection is also influenced by soil moisture at the time of sowing. The seed bed may be just damp enough to allow the spores to germinate while insufficient for *jowar*. In this case the germ-tubes perish before infection can take place. When the moisture is more than sufficient for both the fungus and the host the germination

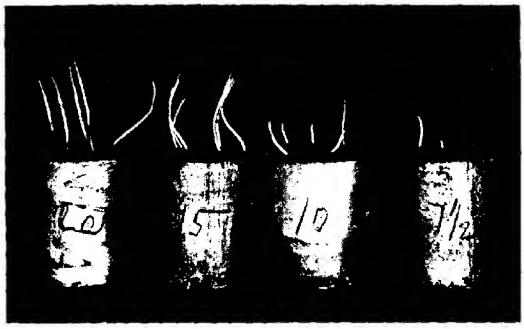
[1] The general rarity of these smuts in the Indo-Gangetic plain, *viz.*, Sind, the Punjab, United Provinces, and Bihar, also seems to depend upon the temperature factor. In all these provinces the average temperature at the sowing time is between 32°C. and 38°C. which is too high for the spores to germinate and therefore infection is very little. Laboratory and field experiments are in hand to confirm this.

of seed is so rapid that the young seedling may outstrip the germinating spores and thus be too far advanced for successful infection to take place. Thus it was found that 2·5 and 5 per cent. water added to air-dried soil was not sufficient for the seed to germinate but was enough for the spores to sprout; while with 7·5, 10, 15 and 20 per cent. *jowar* seed germinated easily, the rapidity of growth of seedlings being dependent on the quantity of moisture, the greater the moisture the more rapid the growth. The photograph (Plate VI) shows well the relative rapidity of germination according to the quantity of moisture after three days. It will be noted that plants in the 20 per cent. moisture pot are the most vigorous and the tallest. Those in 15 per cent. are a little shorter than the first. Those in 10 per cent. are still shorter, and those in the 7·5 per cent. are the shortest.

Laboratory experiments. These were done to determine exactly the part of the seedling at which infection takes place. Seedlings were raised in sterilized Petri dishes, and the seeds before sowing were washed in $\frac{1}{2}$ per cent. formalin for two minutes. Infection in both the Grain and Loose Smuts was most common in those seedlings whose seeds were dusted with spores before sowing. Attempts made by placing germinated or ungerminated spores on the mesocotyl or on the coleoptile were not successful, but in a few cases infection took place in plants whose coleoptile was removed and spores placed on the young leaves. In the infected plants from these seeds which were dusted with spores hyphæ were found most abundantly near the upper part of the mesocotyl at the node from which the coleoptile arises and not towards the base. This shows that infection takes place in the very early stage when the mesocotyl is just being formed.

After infection of the primary shoot the hyphæ rapidly grow into long, irregularly branched, thin-walled, hyaline threads, that ramify freely into the tissues of the plant. They run between and through the cells and some grow straight towards the growing point. They are mostly found in the ground tissue surrounding the central vascular tissue and also in the cells round the bundles when they are separated. They are also seen in the base of the leaf-sheath and in the lower parts of the first leaves. Septa are not clearly seen in the young growing hyphæ but can be made out in older threads. Frequently the cell walls are swollen, and consequently the hyphæ have a lobulated appearance. In full-grown plants the hyphæ become more limited to the intercellular spaces and send in haustoria, which are seldom spherical but most frequently like a bunch of grapes. In the internodes they are usually few and scattered, being most abundantly found at the nodes. Though the mycelium seems to penetrate the entire plant,

PLATE VI



Germination of *jowar* in air-dried soil in four pots, to which had been added 20, 15, 10, and 7·5 per cent. (by weight) of water respectively.

it does not seem to be continuously connected. At the nodes it remains dormant, and when fresh shoots are formed it enters into them and causes the attack of lateral shoots as already mentioned.

Once the growing point of the host is reached the mycelium follows the upward growth of the plant by its continuous growth, producing no apparent effect on its host until the formation of the ear. Then the hyphæ accumulate in the young ovaries below the epidermis, forming a solid mass of considerable depth, and by their pressure the epidermis on the outside and the tissue cells inside are gradually crushed and disorganized. The outer part of the fungus tissue forms the membrane, while the spores are formed in the rest of the fungal mass progressively from without inward, the final result being the sorus with its membrane outside, a mass of spores within, and a part of the vascular tissue of the host left as the columella in the centre.

Even after successful infection has been accomplished the fungus may not be able to keep pace with the fast growing shoot which may escape and produce a sound head. In such cases the hyphæ remain dormant at the nodes and may infect the side shoots when they appear.

While it is mainly through the wind that the spores are carried to the sound grains either in the standing crop or in the threshing yard, it is highly probable that small black beetles are also concerned in it, for they are invariably seen flying about on the smutted heads.

Some smuts are known to be injurious to the health of men or animals fed on smutted grain. Thus maize smut is said to produce the same bad effects as ergot. The green fodder of *Glyceria spectabilis* affected with *Ustilago longissima* is known to be injurious to cattle[1]. Bunt in wheat is said to be harmful to pregnant animals and is known to affect seriously the egg-laying capacity of fowls in Australia[2]. But so far as experience goes in the Bombay Presidency, no instances of these with regard to the *jowar* smuts have been recorded, nor have any complaints been heard recently. Cultivators are in the habit of feeding the smutted plants to cattle without noticing any ill effects on them. The young sorus of the Whole-head Smut is eaten by children with impunity. Nor has the smutted grain been known to cause any derangement in the health of persons who use it for food.

Nomenclature.

There is still a considerable difference of opinion among mycologists with regard to the naming of some of these *jowar* smuts. No two

[1] Eriksson. "Giftiges sussgras von Ustilago longissima befallen". *Zeitschrift fur Pflanzenkrankheiten*, 1900, p. 15.
[2] McAlpine. *The Smuts of Australia*, p. 81.

writers seem to agree, and even in recent literature these smuts have been placed under different genera. There are in all six kinds of smuts recorded on *jowar*. On referring to the descriptions and illustrations of these in recent literature, and also comparing with the specimens in the Pusa herbarium where all the Indian material and some foreign exsiccata are found, these smuts have been determined as under.

(1) Grain Smut, *Sphacelotheca Sorghi* (Link) Clinton. Vernacular names: Marathi—Dane kani, Karde kani; Kanarese—Kalugadige, Godigadige.

This was first recorded on *jowar* in 1825 by Link who named it *Sporisorium Sorghi*[1]. In 1847 Tulasne called it *Tilletia Sorghivulgaris*[2], and in 1873 Passerini named it *Ustilago Sorghi*[3]. In 1874 Kühn, having studied its germination, called it *Ustilago Tulasnei*[4]. Clinton in 1897 from a study of the mode of its spore formation transferred it to the genus Cintractia[5], and finally the same author put it in Sphacelotheca in 1902[6]. The following is the technical description.

Sori formed of pistils and stamens blended together, occasionally the latter escaping, forming a conical body, slightly bent when long, from 3 to 12 mm. in length and 2 to 4 mm. in breadth, at first protected by a greyish membrane which on rupture liberates spores, leaving a distinct columella in the centre formed of host tissue. Spores in mass dark brown, singly brown, smooth-walled, and 4 to 6μ in diameter. The fungus membrane is from 30 to 80μ in thickness and is composed of hyaline, subglobose or oblong cells, and in the early stage bounded by one layer of epidermal cells of the host.

On *Andropogon Sorghum* throughout the Bombay Presidency.

(2) Loose Smut, *Sphacelotheca cruenta* (Kühn) Pot. Vernacular: Marathi—Kajali.

This smut was first described by Kühn in 1872[7] as *Ustilago cruenta*. The chief distinguishing characters which he noticed were the red colouration and the formation of pustules on the panicle branches. As these characters are not constant it has been frequently confused with *S. Sorghi*. Brefeld[8], who also studied it, at first did not consider it as a distinct species although afterwards he separated it from *S. Sorghi*. Clinton does not mention it. Potter[9] called attention to it in 1912.

[1,2,3,4] Quoted by Clinton. "Broom corn smut". *Ill. Agri. Exp. Sta. Bull.* 47, p. 403.
[5] *Ibid*, page 388.
[6] "North American Ustilagineæ." *Proc. Boston Soc. Nat. History*, XXXI, p. 38.
[7] Quoted by Potter, A. A. *Phytopathology*, V, 1915, p. 149.
[8] Quoted by Potter, A. A. *loc. cit.*, p. 150.
[9] Potter, A. A. *Phytopathology*, II, 1912, p. 98, (Abstr.).

It was Busse[1] in 1904 who first noted the fragile character of the membrane of the sorus—the chief and constant character—and recently in 1915[2] Potter described it again pointing out clearly the differences between it and *S. Sorghi*. Our specimen agrees in every respect with his description.

Sori in the ovaries, sometimes on the rachis and its branches, forming an oblong, club-shaped body, tapering to a point, from 3 to 18 mm. in length. Membrane very transient, spores dark in mass, singly darker brown than the last, with minutely pitted walls, 4 to 8μ in size. Columella long and curved.

The glumes of the spikelets are enlarged. The membrane is from 20 to 40μ in thickness and consists of round cells which are sometimes seen mixed with spores. This is also surrounded by a layer of host epidermal cells.

On *Andropogon Sorghum* (mainly on the Rabi varieties) in the Sholapur District.

(3) Long Smut, *Tolyposporium filiferum* Busse.

Busse[3] described this fungus for the first time from East Africa in 1905. The Indian specimen agrees with his description.

Sori in the ovaries, cylindrical in shape, often bent, from 6 to 25 mm. in length, protected by a greyish membrane which on rupture exposes spore mass from 40 to 120μ, irregular in shape, granular in character, consisting of spore-balls which are quite firm. Spores are brown, globular or oblong, with tubercled walls at the free side, and from 8 to 14μ in size. Columella consisting of 8 to 10 fine threads which are joined at the base. The membrane is composed of fungus cells and is from 40 to 80μ in thickness.

On *Andropogon Sorghum* in Sind.

(4) Whole-head Smut, *Sorosporium Reilianum* (Kühn) McAlpine. Vernacular: Marathi—Ziprya; Kanarese—Budigadige, Hittugadige, Chontigadige.

This smut was first described by Kühn[4] in 1875. Saccardo[5], 1876, de Toni,[6] 1888, and Norton[7], 1896, noticed the aggregations of spores suggestive of Sorosporium. Clinton[8] in 1900 mentioned it under Cintractia and in 1902[9] under Sphacelotheca, McAlpine[10] in 1910 placed

[1] Busse, W. "Krankheiten der Sorghumhirse". *Arb. Biol. Anst.*, IV, 1904, p. 319-426.
[2] Potter, A. A. *Phytopathology*, V, p. 149.
[3] Busse, W. *loc. cit.*, p. 383-86.
[4, 5, 7] Quoted by Potter, A. A. *Jour. Agri. Res.*, II, p. 340.
[8] Clinton G. P. "The smuts of Illinois Agri. plants." *Illi. Agri. Exp. Station Bull.* 57, p. 346.
[9] Clinton, G. P. "North American Ustilagineæ." *Proc. Boston Soc. Nat. Hist.*, XXXI, p. 393.
[10] McAlpine. *The Smuts of Australia*, p. 181.

it, owing its formation of spore balls in the early stage, in the genus Sorosporium, and Potter,[1] 1914, agrees with him. The writer also noticed, on sectioning immature sori, spores developing around fibro-vascular bundles in groups in the earliest stages. The appearance agreed with the illustrations of McAlpine and Potter.

Sori very prominent, appearing mostly in the ears, often on the stem and upper leaves, at first enclosed by the leaf-sheath, protected by a transient whitish membrane which on rupture exposes a black spore mass and the ray-like remains of the peduncles or columellas. Spores round or angular, minutely verruculose, 9 to 14μ in size. Sterile cells, often in subspherical groups, are seen scattered through the spores.

The membrane is composed of fungus tissue formed of long threads consisting of oblong cells and is from 60 to 150μ in thickness.

On *Andropogon Sorghum* found sporadically throughout the Bombay Presidency. This was once found on maize at Dohad in 1910.

Preventive Measures.

The cultivators, although they are quite ignorant of any efficient remedy to prevent smut, still follow certain practices, which, though crude and ineffectual, are in the right direction in that they secure the destruction of affected plants and seeds. Thus in the Southern Maratha Country the cultivators are in the habit of picking out smutted plants from the standing crop and feeding them to cattle. This is not done with any intention of checking the disease but simply because they know these plants will not produce any grain, and in doing this they follow a sound principle in disease control, *viz.*, the destruction of affected plants. In this way a good many plants are removed before the crop ripens. Again at the harvesting time the smutted heads are sorted out and separately threshed, though in the same yard and just near the sound heads, and the little grain got from such heads is not mixed with the general produce. Thus a large quantity of the infective material is removed, and consequently the general contamination of the seed is minimized. Again in some places of the Karnatak there is a practice which not only avoids the general distribution of such affected seed but aims at its complete destruction too. This is due to a superstition among the people that the seed got from smutted heads is the gift of the Goddess of Wealth, which is to be kept solely for the use of the family and not by any chance sold with the other produce of the farm or given away even in charity. Cultivators, therefore, take particular care to make it into bread and consume it at home.

[1] Potter, A. A. *Journ. Agri. Res.*, II, p. 341.

As to the origin of this belief it may be suggested that a wise man in former times discovered the true reason for not mixing the diseased seed with the sound. The difficulty would then be to find out a rule to suit the people whereby the discovery might be brought into practical use. Had he tried to make use of it by stating that by mixing the smutted seed with the normal grain one would get more smut in the coming crop, he would not have been heard at all. He might then think of popularizing his methods of dealing with the disease by working on the superstition of the cultivator and inculcating the idea that to part with the grain from smutted heads is to incur the wrath of the Goddess of Wealth.

As already known infection of the plant takes place through the seed-borne spores at the seedling stage in the case of Grain and Loose Smuts. One way to prevent this would undoubtedly be to use seed entirely free from smut spores. But this is by no means an easy thing to do owing to the ubiquitous presence of the disease in every field except the Government Farms, where by continuous preventive efforts the smuts are completely checked. Again, even apparently clean seed is no guarantee unless its source is known, as the adhering spores are too small to be seen by the naked eye.

Another way is to treat the seed with some fungicide so as to kill the adhering spores without in any way injuring the grain. For this purpose various kinds of treatments and chemicals are used in Europe and America, such as hot water, formalin, copper sulphate, corrosive sublimate, potassium sulphide and so on. Among these the first three remedies are those that are usually recommended. In the hot water treatment the grain is first heated in warm water for a few minutes and then immersed in water at about 135°F. for 10 to 15 minutes. Below 130°F. does not kill the spores and above 140°F. is dangerous to the grain. This treatment, though quite effective and highly advocated in America, is troublesome and complicated as it requires the seed to be treated at a particular constant temperature. A little neglect in the operation may seriously injure the germinating capacity of the grain. Besides when large quantities of grain are to be treated it becomes a lengthy and tiresome process. It is therefore not suited to the Indian cultivator who is too ignorant to understand the technicalities of this treatment owing to his illiteracy. What he requires is an easy, quick, and cheap method, and the material must be got easily. The formalin treatment too, which is being adopted on a large scale in foreign countries, is not suited to the Indian conditions as formalin is difficult to get except in very big cities.

The copper sulphate remedy is the only one which fulfils all the requirements. There is one possible objection to this treatment, namely, that it may injure the germinating capacity of seeds treated. Thus it is well known that this method is somewhat injurious to cereals such as wheat, barley, and oats. Recently Mr. Ajrekar, Assistant Professor of Mycology, Agricultural College, Poona, also experienced a similar injurious action of $CuSO_4$ treatment in the germination of sugarcane sets while experimenting with the sugarcane smut.[1] In order to determine how far it is true in the case of *jowar* the following experiment was made. Seed was treated in different strengths ranging from $\frac{1}{2}$ per cent. to 5 per cent. for 10 minutes, and after drying completely its germinating capacity was tested in the seed-testing laboratory of the Agricultural College, Poona. The following are the average results of 5 trials.

No.	Strength of $CuSO_4$ solution	Time for which seed was dipped	Percentage of germination
1	Normal seed . .	....	90·5
2	Seed dipped in $\frac{1}{2}$ % .	10	91·0
3	„ „ 1 % .	10	93·0
4	„ „ 2 % .	10	91·5
5	„ „ 3 % .	10	90·5
6	„ „ 4 % .	10	83·0
7	„ „ 5 % .	10	82·5

It is clear from the experiments that seed can be dipped in solution even up to 3 per cent. strength safely.

Next it was necessary to determine the minimum strength of $CuSO_4$ required to prevent smut. Various workers have recommended various strengths according to the kind of smut. Even in India different strengths are advocated in different provinces. In Bombay, Mollison advocated $\frac{1}{2}$ per cent. for 10 to 15 minutes. McRae in Madras advocates 2 per cent. for 15 minutes. Coleman in Mysore advocates either $\frac{1}{2}$ per cent. for 16 hours or 1 per cent. for 15 minutes. In the Central Provinces 2 per cent. is advocated. The following experiments were conducted to ascertain the exact strength. Seed was mixed with spores and was then divided into four lots. One lot was sown as untreated,

[1] The *Agricultural Journal of India*, vol. XI, part III, p. 294, July 1916.

and the remaining three lots were treated with different strengths for 10 minutes as seen below.

Place and kind of smut	Strength of solution	Percentage of attack
College Farm, Poona— Loose Smut, Plot No. 1 . . .	½ per cent. for 10 minutes .	nil
„ „ 2	1 per cent. „ „ .	nil
„ „ 3	2 per cent „ „ .	nil
„ „ 4	Seed untreated	60 per cent.
Ganeshkhind Botanical Gardens, Kirkee, Poona— Grain Smut, Plot No. 1 . . .	½ per cent. for 10 minutes .	nil
„ „ 2	1 per cent. „ „ .	nil
„ „ 3	2 per cent. „ „ .	nil
„ „ 4	Seed untreated	20 per cent.
Ulewadi near Sholapur— Plot No. 1 . . .	½ per cent. for 10 minutes .	nil
„ „ 2	1 per cent. „ „ .	nil
„ „ 3	2 per cent. „ „ .	nil
„ „ 4	Seed untreated . . .	10 per cent.

These experiments show that even ½ per cent. strength is quite effective in preventing smut, and there is thus a large margin of safety before any injurious effect on the seed need be feared.

The effect of treatment on the spores themselves. This was studied to see how far the treatment was effective in killing the spores. Copper sulphate solutions ranging from ½ per cent. to 5 per cent. were prepared in six Petri dishes. In each solution a little quantity of spore was put and was thoroughly shaken so as to wet all the spores and then was left for 10 minutes. Afterwards each solution was filtered and the spores collected on the filter paper were thoroughly dried. They were then placed

separately in nutrient solutions for germination. After 24 hours it was found that in all cases some of the spores were germinating. No exact account was made to determine the percentage, but it was seen even 5 per cent. strength was not sufficient to kill all the spores. The question then arises how it is that strengths from ½ to 2 per cent. are effective in checking the disease in seed treatment. A possible explanation given is that in drying the grains subsequently to steeping the precipitate left on the surface of the seeds may be toxic to the germ-tubes of the spores[1]. This explanation naturally raises the question of the reinfection of the seed after treatment, and the special precautions recommended by some to be taken after the seed is treated, such as not to use smut-infested bags or seed drills not properly cleaned, seem to be quite unnecessary. In order to investigate this question the following experiment was conducted. Three lots of seed were taken, one was treated with 2 per cent. copper sulphate solution for 10 minutes, another with ½ per cent. formalin for 10 minutes, and the third was untreated. When the first two were thoroughly dried, all the three were dusted with smut spores and sown separately.

Treatment	Percentage of Smut		
	College Farm	G. B. Gardens	Dharwar Farm
Seed treated with 2 per cent. $CuSO_4$ and then mixed with spores	nil	nil	nil
Seed treated with ½ per cent. formalin and then mixed with spores	3 per cent.	nil	nil
Untreated mixed with spores	10 per cent.	5 per cent.	3 per cent.

These experiments prove that in the case of copper sulphate treatment reinfection from fresh spores does not take place, and therefore confirm the above theory. In the case of formalin treatment reinfection does take place to some extent. Formalin leaves no deposit on drying and has all evaporated by the time the seed is sown, and consequently there remains nothing on the seed coat to prevent fresh spores from reinfecting.

[1] *Monthly Bulletin of Agricultural Intelligence and Plant Diseases. International Institute of Agriculture, Rome*, IV, no. 7, July 1913, p. 1039.

Thus the copper sulphate treatment can be recommended with confidence[1] to the cultivator against the common smuts (Grain and Loose) of Jowar as a cheap, quick, efficient, and easily practicable method. It is cheap because the material (two *tolas*[2]) sufficient for seed for one acre will not cost more than three pies. It is efficient as it gives cent per cent. results by completely checking the disease. It is quick because it does not require more than 15 minutes, and practicable as it can be practised by anybody.

All one has to do is to procure an earthen or wooden vessel which can be got in any village. Into this pot 100 *tolas* of water by weight are put (when weighing is not possible two measures by an ordinary rock oil bottle will do). The powdered copper sulphate (2 *tolas*) is put into the water and stirred well till it is dissolved. Then the seed for sowing is plunged into the solution and allowed to remain for 10 minutes, after which the liquid is strained and the seed dried; it is then ready for sowing. All this process does not take more than 15 minutes.

This treatment for the Whole-head Smut as already observed is not effective. The only measure that can be recommended is to destroy the affected plants as soon as they appear, before the spores reach the soil. Fortunately the damage caused by this smut is so little that any further measures are for the present unnecessary.

In the case of the Long Smut no remedial measures can be suggested as its life-history is not fully known.

The copper sulphate treatment is now widely advocated by the Bombay Agricultural Department and is practised by the cultivators.

It may be of interest here to give an account of the efforts of the Department in the way of making this treatment widely known to the cultivators. The method is not new inasmuch as it was already known within and outside India. It, therefore, attracted the attention of the very first officers of the Department and was included in the cropping schemes of all the experimental farms wherever they were started. Thus we find it mentioned in the report of the Bhadgaon Farm as early as of 1885, in the first report of the Surat Farm, and in that of the Dharwar Farm. In those early days as there were no special district officers of the Department, the information used to reach the cultivators through the Revenue Officers. The first strenuous attempt in this

[1] This treatment is not quite satisfactory in the case of those varieties of *jowar* whose grain coats have any peculiarities which would interfere with the solution wetting them completely. Thus in the case of a few fodder varieties, such as American sorghum, *Nilwa*, and *Sundia* where most of the grains have their glumes on them, the spores lying between the glumes and the seed coats escape as the solution does not reach them. The same is the case with oats too. In such cases formalin should be tried.

[2] Two and a half tolas=An ounce.

direction was made in 1905. A note was drawn up on smut and its treatment. This was issued to all the Collectors and repeatedly communicated to the vernacular papers. In 1909 special district officers known as Divisional Inspectors of Agriculture were appointed, and since then the advice began to reach an increasing number of people every year. The first departmental leaflet was issued in the same year and the steeping process became a feature of all shows and exhibitions. People were shown the efficiency of the treatment on the Government Farms and demonstration plots. A further change took place in 1910 when the writer was appointed Assistant Mycologist to the Department. He soon found that with all the activities of the Department the progress was very slow. The reason of this comparative slow success of the methods previously used to push on the steeping practice among the cultivators, was that the shows and demonstrations and other activities of the Department were chiefly carried on at a time rather remote from the sowing time. It thus happened that the cultivator either forgot all about the demonstrations or his enthusiasm was much diminished and he did not make use of his knowledge. The writer thought, therefore, that the proper way was to approach the cultivator directly at the sowing time and get him to do steeping in some part of his fields. The work was accordingly started by the writer in 1911 at different centres in Satara and Belgaum districts. That year in all 13 villages were visited and seed sufficient for 10,000 acres was treated. A second visit was made at the harvest time, and the decided advantages of the steeping practice, which were very evident in the treated fields, were impressed upon the minds of the cultivators. A report on the work was submitted to the Director of Agriculture proposing to continue this process of approaching the cultivators at sowing time on their own fields. As a result of this report the district staff was instructed to carry on the work, and consequently in the following year 1912 seed for a much larger area than ever before (extending over 150 villages of seven districts, *viz.*, Surat, Broach, Sholapur, Satara, Bijapur, Belgaum, and Dharwar) was treated. A second report was submitted on the results of this work and the necessity of continuing the campaign against this most common but easily preventible malady was urged. The work was taken up very enthusiastically by the district staff, and as a consequence a good many cultivators began to practise it as one of the operations in the cultivation of the crop. This increased work naturally created a large demand for copper sulphate. In order to meet this demand and to distribute copper sulphate and a knowledge of its use into the remotest corners of the Presidency, small packets of copper sulphate were prepared, worth an anna, containing material

sufficient for treating seed for four acres and with instructions for use printed in all the vernaculars of the Presidency. Since this system was introduced the practice of steeping has been rapidly extending among the cultivators. The increase in popularity of this measure can be seen from the following table :—

Year	Number of packets sold	Number of shows and demonstrations		Number of cultivators who visited the demonstration plots
1913-14 . .	4,000	10	111	To the Poona Farm 2,249 people came from the 26 talukas of the Central Division. To the Dharwar Farm 1,000 from the three districts of Bijapur, Belgaum, and Dharwar; 200 came to the Surat Farm.
1914-15 . .	40,000	4	62	800 to the Poona Farm from the four districts of Poona, Satara, Sholapur, and Ahmednagar. Dohad Farm 30, Dhulia Farm 800, Ahmednagar 75, Vadala 100, Dharwar 683.
1915-16 . .	43,455	7	150	850 to the Poona Farm from Satara, Ahmednagar, Nasik, and Sholapur districts. Dohad 100, Dharwar 100, Gokak 300.

It is satisfactory to note that in a good many places Revenue Officers, Agricultural Associations, Co-operative Societies, and many public-spirited men[1] are also helping the Department in selling these packets. Many cultivators are now obtaining copper sulphate from other sources and using it. The propaganda is being carried on very vigorously in the Southern Division. In 1914-15 an extensive campaign was undertaken and steeping was demonstrated in 75 villages of the Sholapur District, 17 of the Satara

[1] It should be noted here that the suggestion with regard to the packets originally came from Mr. Sabnis of Savadatti, Belgaum District, one of the most enthusiastic local workers in the cause of agricultural improvement. The packets are prepared for the Department by Mr. A. B. Modak, Proprietor, The Union Agency, Prag Mahal, Bombay. Mr. Modak has also been greatly instrumental in popularizing these packets.

District, and in 21 talukas of Belgaum, Bijapur and Dharwar districts. In 1915-16 the campaign was undertaken on a still more extensive scale, and as a result there was hardly any important village where the steeping had not been demonstrated. Already some villages (Hulkoti and Kurtkoti) in the Southern Division are now quite free from smut. In the Central Division Mr. Knight, Professor of Agriculture, has made a move on the same line and work has been started in a village near Poona. From the number of packets sold it is evident that the cultivators must have prevented a loss amounting to a million rupees. This is a substantial testimony of the practical and monetary value of the mycological branch of the work of the Department. However, this saving is small when compared to the annual total loss of twenty million rupees. But every effort will be made to push on this propaganda, and it is hoped that in the near future the disease will be for all practical purposes exterminated and the large losses caused to the cultivator minimized.

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